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4.—The mineral resources of Western Australia and their potential

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Abstract

The history of mineral production over the past 124 years is outlined, and the present development and the potential of the more important minerals such as iron, petroleum, bauxite, gold and nickel is discussed. The value of mineral production should increase from the present $A53 to $A245 million per year during the next five years, while intensive prospecting may locate new major deposits of such minerals as copper, lead, nickel, potassium salts and phosphates.

Introduction

Like many other States and countries, the development of Western Australia can be linked closely with the development of the State's mineral resources. Until 1953 gold was by far the most important mineral produced and the total mineral production was largely a reflection of the value of gold won. Coal was the only other mineral mined continuously over this period.

Although some copper was mined near Northampton in 1842, by 1872 the Government of the colony, realising that a gold strike was required to stimulate progress, offered a reward of £5,000 to the discoverer of a field which could produce 10,000 ounces of gold.

In 1885, the Government financed a prospecting venture under the leadership of Hall to examine in detail a portion of the Kimberley area, where in the previous year Government Geologist E. T. Hardman had found reef and alluvial shows of gold. Three years earlier another prospector named Saunders claimed to have found a trace of gold in this area while travelling through to the Northern Territory. Payable gold was discovered on the 14th July, 1885, and by 1886 over 2,000 people were prospecting in the area. The find did not prove as rich as expected and the reported production did not reach the required 10,000 ounces, although the target may have been reached if all of the gold had been sold through the correct channels. An inquiry by a select committee of the Government recommended £500 reward to Hall's party and £500 to Geologist Hardman.

Disappointed in the Kimberley area, the prospectors from other States and overseas drifted southwards, where gold discoveries followed in quick succession in the Pilbara, Murchison, and Yilgarn, and in 1892 Coolgardie was discovered, followed by Kalgoorlie in 1893.

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With the location of the fabulous "Golden Mile" at the latter centre, the population of the State showed its period of greatest growth when it almost quadrupled from 48,502 to 179,967 in the last decade of the century.

Many of the very rich finds were quickly worked out but others persisted and became established mines. On the total mineral production chart (Fig. 2) or on the gold section of Fig. 3, it can be seen that gold reached production peak in 1903 and then began to decline steadily. This decline was hastened during World War I and in the following years.

The disappointed prospectors did not leave the State but turned to other occupations, in particular wheat and wool production. While gold declined, these primary industries developed because of the additional manpower and finance brought to the State, as shown in Fig. 2.

When these new industries suffered from the depression in the 1930's, there was a return to the goldfields, and when the price of gold increased, gold production again rose and helped considerably to cushion the effect of the depression in this State. The rise was again turned to a slump by World War II, but although an upward trend developed on the cessation of hostilities, this recovery was handicapped by the fixed price of gold. For some years, however, the mining engineers managed to overcome this by improved efficiency and techniques, but these methods could not continue to offset the steeply rising wages and costs. By 1953 the production of gold reached the peak of its post-war recovery, remained static for a few years and is now declining (see Fig. 3). This decline must continue unless there is a substantial rise in the price of gold.

About 1953 mining companies began to realize that, even if new gold finds were made, the economic situation precluded their development unless the grade of ore was very high. Gradually therefore, the companies became interested in "minerals other than gold". The interest in these minerals began to increase due to the expanded production of asbestos, iron and manganese and, later, the development of mineral sands in the south-west and bauxite in the Darling Range. In 1964 the production exceeded the value of gold produced for the first time.

It may be asked why these minerals were not developed earlier. There were no doubt many reasons but, in my opinion, the more important cnes were that prospectors and mining com-

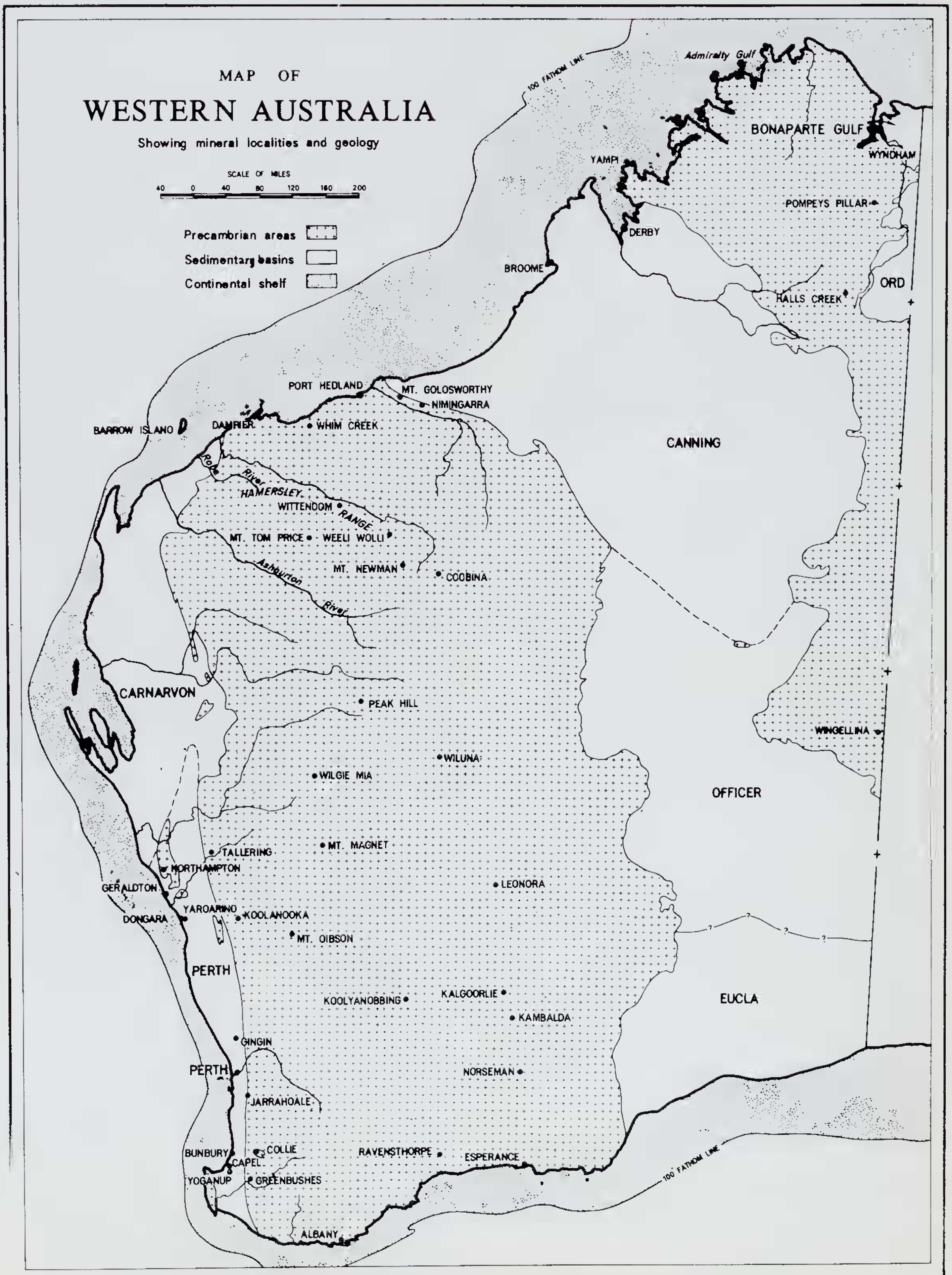

Fig. 1.—Western Australia showing some mineral localities and regional divisions.

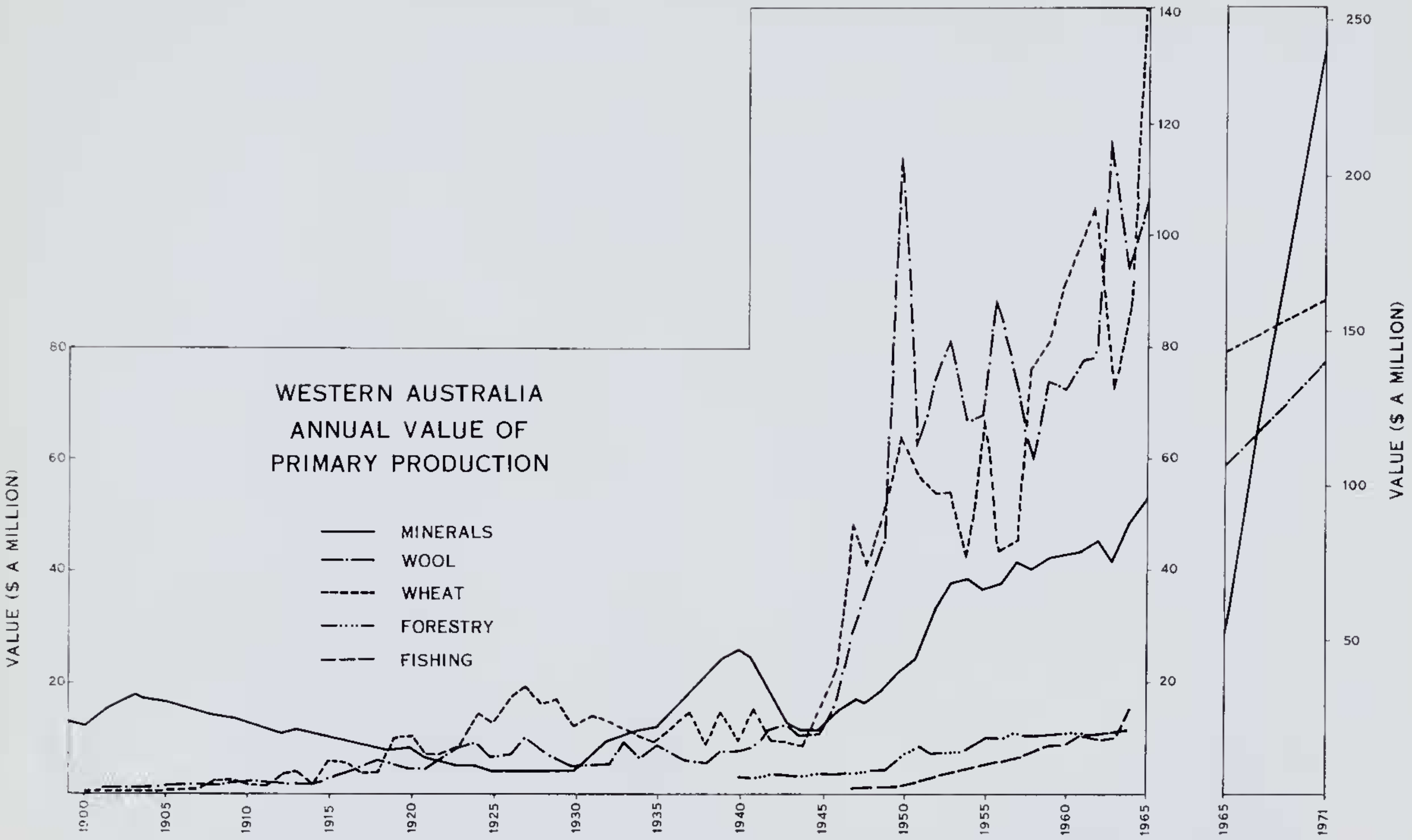

Fig. 2.—Annual Value of Primary Production, Western Australia, 1899 to 1965 and projection to 1971.

panies were too fascinated with the get-rich-quick prospects of gold, and that there was a lack of capital and developed overseas markets for other minerals. The prospector has been interested always in gold, as it is easy to identify and easy to estimate the grade of a find by panning. A rich alluvial patch offers quick rewards, or, if in reefs, it is easy to treat as the Government provides treatment facilities.

The age of the prospector is passing, as the opportunities for quicker rewards from gold are now rare and prospecting for minerals other than gold is more difficult from all aspects. Full credit and recognition must be given to the early prospector who penetrated the isolated areas of this State in his search for gold. Originally the company would wait for the prospector to make a find and then purchase it from him, but nowadays companies are being forced to do their own prospecting. This has resulted in the geologist becoming the modern prospector in the search for surface and concealed ore bodies, using aids which are far beyond the scope or comprehension of the original prospector.

Oil exploration is carried out on a highly scientific basis with the extensive use of geophysics and has led the way in this State with the application of new techniques for prospecting.

Exploration for other minerals in this State is following this lead and now companies are using the latest airborne and surface geophysical techniques and geochemical methods to assist the geologist to unravel the sub-surface structures. These methods are costly to operate and account for the millions of dollars being spent on mineral search. The reward is the increase in the State's total mineral production (see Figs. 2 & 3), since 1952 and the great increase expected within the next few years.

The bauxite in the Darling Range is an example of how new mineral deposits are found or developed. For many years it was known that bauxite occurred here but it was never investigated thoroughly until one company decided to take the risk. It spent thousands of dollars on basic geological studies, detailed sampling, drilling and the establishment of a special laboratory for assaying. Finally, when the bauxite was thought to be present in significant quantity and grade, detailed investigations of the metallurgical problems associated with the treatment of the ore were carried out. The result is the thriving alumina industry at Kwinana.

Before discussing minerals in detail, I should like to mention one mineral which is not shown on any production table, nor is its value reported anywhere in dollars. It is water, which is far more important to this State than any other mineral mentioned below. Its potential is limited and it requires careful conservation to ensure that all the State's future requirements are met. The Government is conscious of this fact and has eleven geologists engaged on the search and evaluation of ground water supplies, which is equivalent to the complete strength of the Geological Survey 5 years ago.

There are many ways of classifying mineral occurrences geologically, but for this general discussion they are considered in three regional groups: firstly, those which occur on or associated with Precambrian rocks; secondly, those which occur associated with sedimentary basins

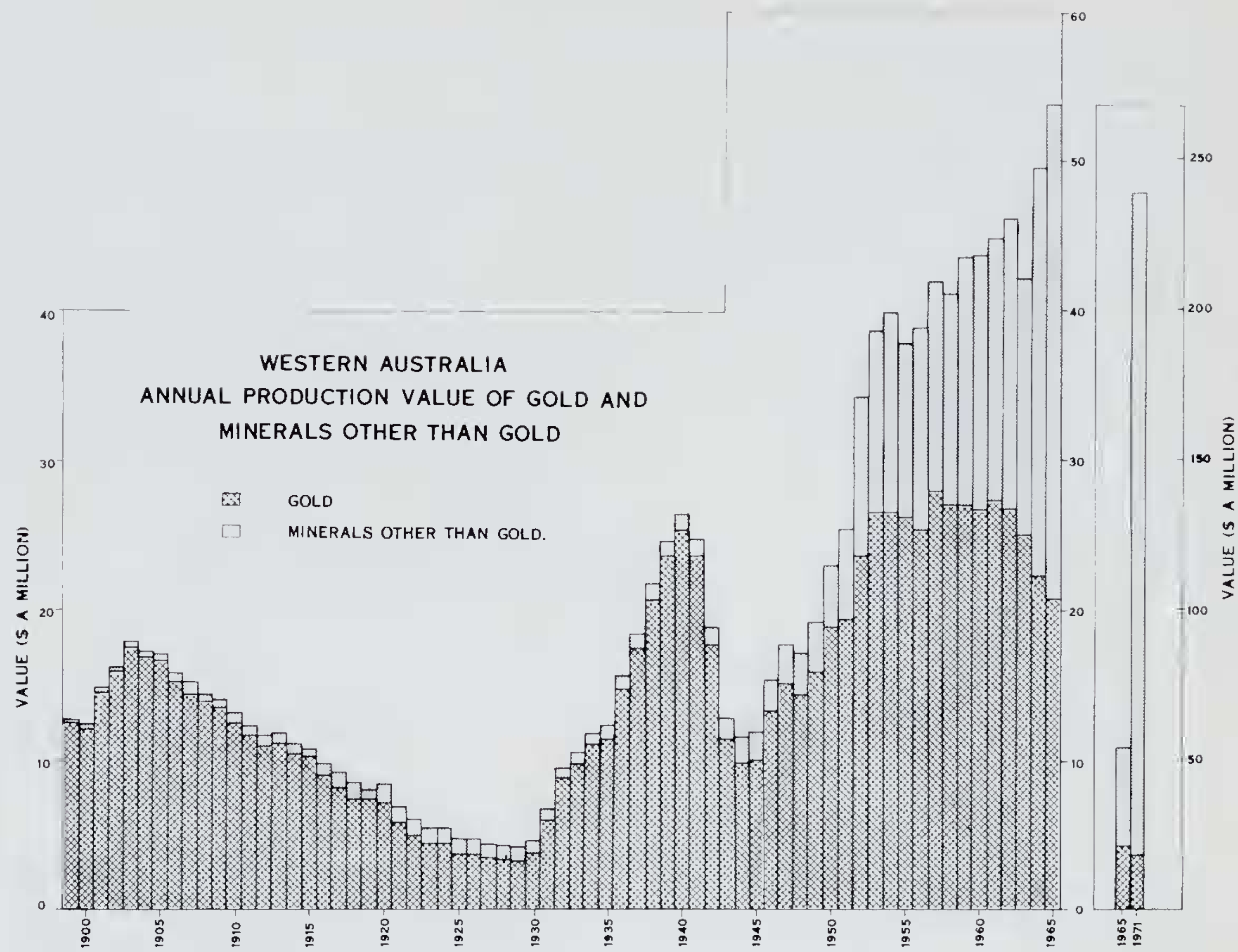

Fig. 3.—Annual Production Value of Gold and "Minerals other than Gold", Western Australia, 1899-1965 and projection to 1971.

and thirdly, those which may occur offshore on the continental shelf. These regional divisions are shown on Fig. 1. Only minerals which are or will be produced on a substantial scale are considered.

Precambrian region

The Precambrian rocks cover an area of over 600,000 square miles or nearly two-thirds of Western Australia (see Fig. 1). The age of rocks covers the full span of the Precambrian from 600 million to over 3,000 million years. Some have been altered physically and chemically many times; others, such as the Brockman Iron Formation, are relatively unaltered, while all have undergone surface erosion over a very long period.

Gold.—Archaean basic lavas, basic and acid intrusives, metasediments and banded iron formation have acted as hosts for gold mineralization, which is estimated to have occurred 2,300 million to 2,400 million years ago. The semi-arid climate and erosion over a long period of geological time have favoured surface enrichment of deposits, while for similar reasons alluvial deposits are rare.

The State has produced 65,538,978 ounces of gold valued at $A1,009,686,910. Kalgoorlie has produced 36,094,574 ounces while Leonora, Norseman, Wiluna, Mt. Magnet and Day Dawn are centres each of which have produced over 1 million fine ounces.

Potential.—The history of the gold industry has been outlined earlier and unless there is a substantial increase in the price of gold, production will continue to decline.

The amount of prospecting already done, indicates that the chances of finding new high-grade deposits at the surface are not favourable. Any large new mines would be on large low grade ore bodies or on concealed ore bodies.

Bauxite.—The aluminous nature of the Western Australian laterites has been known for many years, but their commercial value was not appreciated until Western Mining Corporation carried out an expensive detailed investigation in the Darling Range.

The bauxite, consisting of hydrated oxides of alumina and iron with silica in varying proportions, occurs in the lateritic profile. It contains from 30 to 45 per cent alumina, with silica and iron as the main impurities. The silica is in the form of unreactive quartz and does not create refining problems.

Another occurrence of bauxite has been reported from the North Kimberley near Admiralty Gulf. The occurrence is the text book example of bauxite in the laterite profile over the Carson Volcanics. The deposit is being investigated actively.

Potential.—The deposits in the Darling Range cover many square miles and have not yet been fully assessed. Reserves may amount to hundreds of millions of tons.

The new occurrence in the Kimberley should be of high grade and testing may show it to be a major deposit.

Iron.—Earlier geologists reported the occurrence of large deposits of iron in this State. Woodward in 1888, in a Government publication, stated that the north-west of this State would supply the world when other iron ore resources were exhausted. After 1950 an overseas market developed for iron ore and with the relaxation of the Commonwealth Government's export embargo at the end of 1960, exploration for iron ore became worthwhile. Immediately the north-west portion of this State became the focal point of extensive exploration by major companies and within 3 years the Hamersley Iron Province, as it is now know, was explored and assessed to be one of the major iron fields of the world.

The Hamersley Iron Province consists of a Proterozoic sedimentary succession containing thick and extensive banded iron formations, which are thought to have been deposited as chemical sediments from solutions rich in iron, silica, and carbonates. In general they are only gently folded and unmetamorphosed and contain between 20 and 40 per cent iron and between 40 and 60 per cent silica and carbonates. The most important formation for iron deposits is the Brockman Iron Formation, which is 2,000 feet thick and may originally have covered over 30,000 square miles.

The iron ore is thought to have been formed in structurally favourable localities by leaching of the silica and carbonates and the supergene enrichment of the iron over a long period of geological time. This process has produced large hematite-geothite ore bodies ranging in grade from 55 to 68 per cent iron.

A similar process, in the detritus deposited on the flanks of the banded iron formation and in the adjacent drainage channels, has resulted in the formation of limonite-geothite ores ranging from 50 to 60 per cent iron.

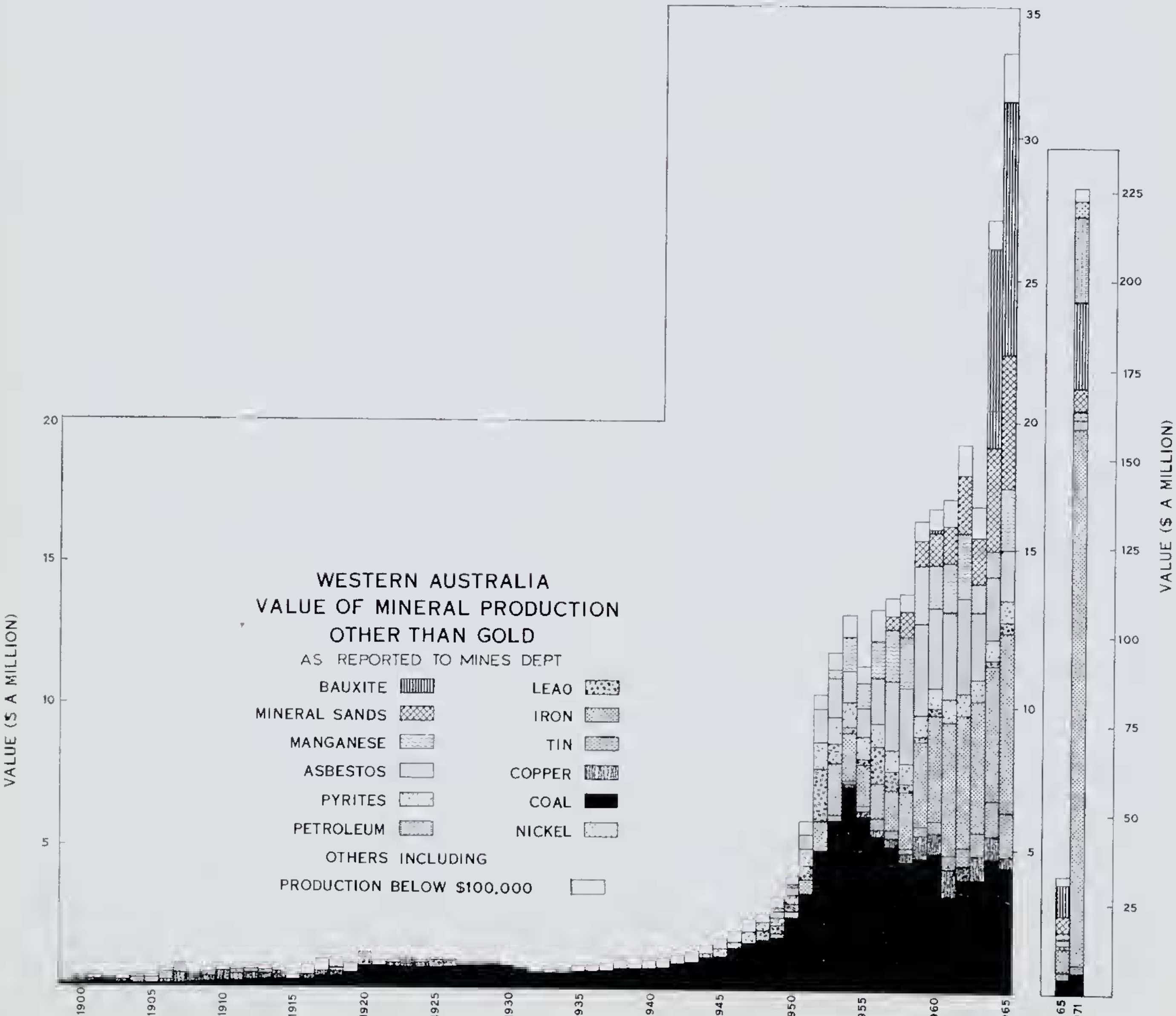

Fig. 4. Value of Mineral Production other than Gold, Western Australia, 1899-1965 with projection to 1971.

The Archaean rocks of this State contain steeply dipping and strongly folded iron formations, which have been subjected to deep and protracted erosion and metasomatic replacement. It appears that most of the iron ore deposits, which occur as massive concordant lenses, have originated by selective leaching of silica from jaspilite. These Archaean deposits are widely distributed over the north-western and southern portions of this region.

In the Kimberley Division occur iron ores of clastic sedimentary origin which were probably formed by the concentrating action of water along old shorelines. Such deposits occur at Yampi Sound, Pompeys Pillar and in the Bandicoot and Osmond Ranges.

Potential.—In the words of Woodward in 1888 there is "sufficient (iron ore) to supply the world". The inferred iron ore reserves of the State exceed 15,000 million tons, with an iron content of 50 per cent or more. About 8,000 million tons of this are high grade hematite ores with an iron content of 60 per cent or better. Over 1,000 million tons have been proven by drilling to average more than 64 per cent iron with low phosphorus content.

In the Hamersley Iron Province, where over 90 per cent of the ore reserves occur, at least 100 ore bodies have been recognized. The two major hematite deposits investigated and being developed are at Mt. Tom Price and Mt. Newman, each of which have reserves of over 500 million tons. Other hematite deposits occur at Mt. Brockman and Weeli Wolli Spring. The pisoltic-limonite-goethite ores are most abundant in the valleys of the Robe and Beasley Rivers and Duck Creek.

The Archaean hematite deposits are scattered widely over the State. Export of iron ore of this type has commenced from Koolanooka and Mt. Goldsworthy, and the Koolyanobbing deposit is being developed to supply ore to a blast furnace at Kwinana, near Perth. Deposits at Mt. Gibson, and Wilgie Mia in the Weld Range, are being investigated for export feasibility. These deposits range in size up to 70 million tons of high grade (60 per cent plus) ore and are in some places associated with larger tonnages of low grade ore. In the Kimberley region deposits at Yampi Sound have reserves estimated to be 78 million tons, while the other deposits located have not proved suitable for development as direct shipping ore. However, in the future they could be suitable for beneficiation and pelletization.

Asbestos.—Crocidolite (or blue asbestos), a fibrous variety of the alkali amphibolite riebeckite, occurs extensively in the Hamersley Range. It is mined at Wittenoom Gorge where seams range from ¼ to 2½ inches in width and are interbedded with the cherty iron carbonate beds of the Brockman Iron Formation.

Chrysotile (or white asbestos) occurs at numerous localities in the Archaean rocks, particularly in the Pilbara and West Pilbara Goldfields. Production has been only on a minor scale.

Potential.—Providing satisfactory markets can be established and the present grade proved to be economical, there is a reasonable potential for the future development of blue asbestos in the Hamersley Range, while exploration for white asbestos may locate deposits worthy of major development.

Manganese.—At present Western Australia has been Australia's major producer of manganese ore, but with the discovery of large continuous deposits on Groote Island this position may change shortly. Production in this State has been from the Pilbara area and from Horseshoe near Peak Hill.

Usually the deposits are formed as a result of supergene enrichment of manganiferous sediments or by precipitation near the surface of manganese derived from the sediments. Rarely do they extend to depth, except in a few cases which, as they are the result of cavity filling, may have only a small surface expression and may continue to greater depths.

The ore bodies range in size from a few tons to several thousands, and in rare cases, hundreds of thousands of tons. Most of the ore bodies are in the 500 to 5,000 tons range with an average grade of 45 to 50 per cent manganese.

Potential.—Due to the nature of occurrence of of manganese, mining has been spasmodic and remains in the hands of small operators. No alteration can be seen in the future.

Tin.—At Greenbushes, where tin was first discovered in 1888, cassiterite occurs in association with tantalite in veins in greenstone and granite, which has produced detrital accumulations in the overlying alluvium. A little lode tin has been mined.

In the Pilbara goldfield, cassiterite, derived from albitized pegmatites associated with Archaean rocks, occurs as eluvial or detrital accumulations near the host pegmatites or from alluvial concentrations in present and past drainage channels. Tantalite and columbite are common associate minerals.

Potential.—The tin deposits of this State are small and flourish only when the world market price is high, as at present. There does not appear to be any possibility of a major long term expansion in production.

Copper.—Copper deposits have been found throughout Precambrian rocks, mainly as narrow copper-gold-quartz veins in various types of metasediments and basic igneous rocks. Most deposits have been only small producers in the oxidized or secondary enriched zone. The grade in the primary zone has been too low to warrant development. The largest and richest mine, at Whim Creek, produced only 9,918 tons of metallic copper.

Potential.—With the large number of occurrences throughout the State, one must be optimistic that a major deposit will be located. The Bangemall Group in the Ashburton Valley may prove the host for such a find.

Lead.—Over 80 per cent of lead production in this State has come from the Northampton Mineral Field, where lead ore bodies occur in shear zones in gneiss associated with quartz veins. The lodes are not large or persistent, with the result that mining is on a small scale and most activity is restricted to periods of high world lead prices. Lead occurrences have been recorded from many localities throughout this region.

Potential.—Like copper, the prospects of finding a large lead deposit are considered reasonable and again the Bangemall Group in the Ashburton Valley is worthy of extensive and detailed prospecting.

Nickel.—The possibility of major nickel ocurrences existing in this State has long been neglected, which is difficult to understand, considering the known wide occurrence of ultrabasic and serpentine rocks, which serve as hosts for nickel mineralization. In the late 1950s nickel mineralization was located near the eastern border of the State and at Wingellina, where it occurs as garnierite in laterite developed over ultrabasic rocks. Although the deposit is still being explored the geographical position makes development of a mine very difficult.

At Kambalda, 30 miles south of Kalgoorlie, an economic deposit of nickel sulphide in pyrrhotite was located recently in a structure near the contact of ultrabasic and serpentine rocks. This geological environment is being prospected actively by mining companies and some nickel mineralization has been located. Geophysical and geochemical anomalies indicate that further prospective zones exist.

Potential.—With one mine being developed, and favourable prospects of finding additional ore bodies, this State could become a major nickel producer.

Sedimentary basins

The Perth, Carnarvon, Canning, Bonaparte, Officer, and Eucla sedimentary basins together cover nearly 400,000 square miles of the State. Although extensively faulted in places, the sediments are not highly altered and only two small areas have igneous intrusions, one in the northern part of the Canning Basin and the other in the southern portion of the Perth Basin.

It is only in the last 15 years that the sedimentary basins have been investigated in a serious manner for possible mineral occurrences and, because of the large area involved in many instances, it has been necessarily in a very cursory manner.

Oil and Gas.—The first "oil boom" occurred in this State at the beginning of the century and the earliest oil wells were drilled near the Warren River at the south end of the Perth Basin. The next period of interest commenced in 1919 when traces of oil were found in a water bore on Gogo Station on the northern side of the Canning Basin. This resulted in the formation of the Freney-Kimberley Oil Company, which, operating spasmodically, drilled a number of unsuccessful holes in the Canning Basin, until taken over by another company in 1954. An American company commenced detailed investigations in the Canning Basin in 1940 and 1941 but ceased operations due to the War.

The first large-scale exploration, employing the full range of modern techniques, began in 1952 with the formation of West Australian Petroleum Pty. Ltd., commonly known as Wapet.

In their first hole, Rough Range No. 1, in 1953, oil was produced at a rate of 500 barrels per day from the lower Cretaceous sands of the Birdrong Formation at a depth of 3,602 feet. Subsequent drilling showed that this oil occumulation was too small for commercial development at that stage.

This initial success was followed by 11 years of fruitless search and it was not until 1964 that the company made another significant discovery when oil and gas were found on Barrow Island and also near Yardarino. More recently, oil and gas have been found at Mt. Horner and at Gingin, Arrowsmith and Dongara, all in the northern portion of the Perth Basin.

The Barrow Island discovery has been declared commercial and production is planned from the top oil horizon, the Lower Cretaceous Windalia Radiolarite at the depth of 2,500 feet. This formation lacks permeability and modern fracturing techniques will be used to recover the oil. Upon the success of this technique depends the final quantity of oil which will be recovered. The very conservative estimate of the recoverable reserve is 85 million barrels which will give a productive life to this horizon of about 12 years at the present rate of production.

Deeper Jurassic formations between 6,000 and 7,500 feet are structurally more complicated and the full assessment of their oil potential has yet to be completed. It is known that the sands are more productive and contain a variable amount of gas, but the area of sands present is probably much less than the higher horizon.

Potential.—With Barrow Island commencing production in 1967 and favourable indications found in some other areas, one must be optimistic that more fields will be discovered. Only 177 drilled holes of all types, of which 26 are on Barrow Island, have been put down for oil search in this State. When the area of sedimentary rocks is considered it is easy to realize that the search is only just beginning.

Although a gas field has not yet been defined, the prospects in the northern part of the Perth Basin are very good. The time may not be far distant when a gas pipe line network covering the State from Geraldton to Bunbury may be a possibility, providing cheap power and supplying a petro-chemical industry producing fertilizers, plastics, sulphur and other products at some convenient point.

Coal.—Despite the large area of sedimentary basins, this State does not possess good coal resources. The only source of commercial coal is at Collie, a small Permian basin within the Precambrian shield area.

The Collie coal basin covers about 90 square miles and contains three horizons of coal seams. The strata are poorly consolidated sandstones and shales, which have been affected severely by slumping and faulting. As a result, underground mining costs are high and operations difficult and collieries are usually abandoned for these reasons, rather than the lack of coal.

The coal is of low rank, black, non-coking, sub-bituminous and with a calorific value of about 9,000 B.Th.U. as mined today. One feature is the low ash content of 2 to 4 per cent.

Collie coal has been the State's principal source of power since production began in 1898 but because of rising costs it is now used only for the generation of electrical power, which consumes nearly 1 million tons per year. The only coal of better quality located in this State was in the Eneabba No. 1 oil well in the northern portion of the Perth Basin at a depth of over 6,000 feet. It was a lower Jurassic coal with a calorific value of about 12,000 B.Th.U. Exploration failed to locate this coal at shallower depths.

Potential.—There are indicated extractable reserves at Collie, at the present rate of consumption, for the next 50 to 100 years. However, rising costs will have to be halted or otherwise natural oil or gas may capture the power market.

There are still possibilities that sub-surface deposits of coal may be found in other basins.

Mineral Sands.—Mineral sands deposits in the southern portion of the Perth Basin near Bunbury and Busselton have been located and developed in recent years. The establishment of this industry has not been rapid due to the low market price of the principal mineral, ilmenite. Zircon and small amounts of rutile and monazite occur also in the heavy mineral concentrate.

These minerals occur as minor accessory minerals in the Precambrian granitic rocks of the south-west portion of the State. Protracted erosion has liberated large quantities of these accessory minerals, which have found their way to the sea, where its action has concentrated them along strand lines. Due to a number of small uplifts of the coast, the old strand lines with associated heavy mineral concentrations, are now found some distance inland.

Potential.—The reserves held by the operating companies appear adequate for some years allowing for a gradual increase in the production rate.

Continental shelf

There is a mounting interest throughout the world in the search for minerals offshore on the continental shelf and slope. This State with its long coastline and wide shelf, particularly in the north, has a potential search area in excess of 200,000 square miles.

Offshore exploration so far has been confined to airborne magnetometer and marine seismic surveys for petroleum. Within the next 2 years offshore drilling for oil and sampling of the sea floor for minerals should begin. These investigations will be costly but must be attempted and encouraged if this State is to keep abreast of modern trends in exploration.

Potential.—The petroleum potential offshore is encouraging and it is almost certain, as a result of Barrow Island discoveries that further oil fields will be located offshore, particularly from Exmouth Gulf northwards and in the Joseph Bonaparte Gulf.

Other minerals which may be found offshore include phosphates, manganese, tin and ilmenite.

Salt will soon be produced on a major scale at Shark Bay, Port Hedland and Dampier by pumping sea water into constructed evaporating pans on the coastal flats.

The future

The potential of minerals now in production and others which may be produced within the next few years have been discussed. No doubt there are minerals in this State which are of no economic importance at present but which may assume importance in the future; there are also minerals whose occurrences have been recorded but to which as yet insufficient attention has been paid by exploration companies. These include chromium, vanadium, molybdenum and uranium. Amongst the non-metallic minerals, it is hoped that phosphate will be located in economic quantities, and the evaporite formations, located during oil drilling, may disclose commercial deposits of potassium and other salts when examined in detail.

The mineral production of this State is about to undergo a dramatic increase from a total value of $A53.8 million last year (1965) to a possible $A245 million in 1971, as shown in Figs. 2, 3 and 4. This estimate takes into account only the planned and proposed developments. There is no doubt that the major developments in iron, bauxite, petroleum, nickel and mineral sands will stimulate the exploration and development of other mineral deposits.

The Table below shows how the value of production of various minerals may develop and how by the end of 1971 minerals could become the leading money earning industry in this State. In future iron will displace gold as our major mineral and statistics may have to be shown as "iron" and "minerals other than iron".

Acknowledgements

The information used in this address has been drawn from numerous reports of the Geological Survey of Western Australia, by many authors. The statistics were supplied by the Statistical Branch of the Mines Department.

Mineral production of Western Australia
($1Aust. = $1.1U.S. = £0.625 Sterling)

Mineral	1953 $A actual	1965 $A actual	1971 $A estimate
Gold	26,598,000	20,722,000	18,500,000
Bauxite	—	8,908,000	24,000,000
Iron	1,806,000	6,316,000	150,000,000
Mineral Sands	—	4,744,000	6,500,000
Coal	6,146,000	4,410,000	5,500,000
Manganese	302,000	2,152,000	2,500,000
Asbestos	1,414,723	1,804,000	2,500,000
Tin	126,000	1,557,000	2,500,000
Pyrite	980,000	768,000	750,000
Lead	143,000	393,000	400,000
Copper	48,000	334,000	500,000
Petroleum	—	—	24,000,000
Nickel	—	—	4,000,000
Others (inc. salt)	1,089,000	1,697,000	3,850,000
Total	33,657,000	53,825,000	245,000,000